Spawn-on-Kelp Fisheries in the Queen Charlotte Islands and Northern British Columbia Coast - 1982 and 1983

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SPAWN-ON-KELP FISHERIES IN THE QUEEN CHARLOTTE ISLANDS AND NORTHERN BRITISH COLUMBIA COAST - 1982 AND 1983

by

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ABSTRACT

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The herring spawn-on-kelp fishery in British Columbia is an important commerical fishery which can produce a high quality product using a small amount of herring. Investigations of spawn-on-kelp operations on the north coast and the Queen Charlotte Islands were carried out in 1982 and 1983. Herring mortalities were low during the capture, towing, and transfer of herring to impoundments; subsequent high mortalities appear to be the result of excessively high loading densities. Water quality in the impoundments remained high in spite of heavy egg coverage along the inside of the web. Depending on fish maturity and harvest methods, the quota for one licence (7.26 t of product) was estimated to require 28.6 to 63.5 t of hering. This does not consider the quantity of herring lost because of mortality before or after the fishery operations.

Alternative harvest methods such as "open ponds" have several advantages over the more traditional methods but are not suitable for all areas. An important factor limiting the spawn-on-kelp fishery is the availability of high quality kelp.

RÉSUMÉ

Shields, T. L., G. S. Jamieson, and P. E. Sprout. 1985. Spawn-on-kelp fisheries in the Queen Charlotte Islands and northern British Columbia coast - 1982 and 1983. Can. Tech. Rep. Fish. Aquat. Sci. 1372: 53 p.

En Colombie-Britannique, la récolte de rogue de hareng sur varech est une importante industrie qui peut fournir un produit de qualité supérieure à partir d'une petite quantité de poissons. En 1982 et 1983, on a réalisé un examen de ce type d'exploitation sur le littoral nord et dans les îles Reine-Charlotte. Le taux de mortalité était faible au cours de la capture, du transport et du transfert dans les enclos de retenue; les taux élevés observés ultérieurement semblent être le résultat de densités de charge excessivement élevées. Malgré le dépôt important de rogue sur les mailles intérieures du filet, la qualité de l'eau dans les enclos est demeurée élevée. Selon la maturité du poisson et les méthodes de récolte, on a calculé que pour le contingent fixé par un permis (7.26 t de produit), il faut de 28.6 à 63.5 t de hareng. Ceci ne tient pas compte de la quantité de harengs morts avant ou après la récolte.

D'autres méthodes de récolte, comme des "étangs ouverts", présentent plusieurs avantages sur les méthodes plus traditionnelles, mais ne conviennent pas à tous les endroits. La disponibilité de varech de qualité élevée constitue un important facteur limitatif à l'exploitation de rogue sur varech.

INTRODUCTION

Pacific herring (Clupea harengus pallasi) in British Columbia spawn along the shoreline in the intertidal and upper subtidal zones. Their adhesive eggs are attached primarily to marine algae and sea grasses. Indians living along the British Columbia coast have traditionally harvested herring roe deposited on near-shore kelps. After Japan began importing the product from Alaska in the early 1960's, interest grew among Canadian commerical fishermen. The herring spawn-on-kelp fishery began in B.C. in 1971 when an experimental permit was issued in the Queen Charlotte Islands to produce spawn-on-kelp in an impoundment. A second permit was issued for the same area in 1974.

In 1975 the B.C. fishery regulations were amended to allow for the commercial production of spawn-on-kelp. Following a selection process, 13 licenses were issued in 1975; each licence was allowed 5.4 t (6 tons) of product annually. Selection was based on a rating system which assigned points for experience in catching, handling and holding live herring and the remoteness of the operation site (preference was given to applicants from remote communities and special consideration was given to native Indians).

During the period 1976-1978 the spawn-on-kelp fishery was expanded and there were adjustments to the annual allowable quota. In 1976, an additional 8 licences were issued bringing the total to 21. In 1977, the allowable quota per licence was increased to 9.1 t (10 tons) and a total of 24 licences were issued. In 1978, the final expansion occurred when 5 new licences were added; at the same time the allowable quota per licence was reduced to 7.25 t (8 tons).

In 1979, one licence holder exchanged his spawn-on-kelp licence for a roe herring seine licence: this brought the total number of licences issued to 28. No further changes in the number of licences or the allowable quota per licence have occurred since 1979.

Until 1982, the fishery involved each fisherman seining about 90.7 t of sexually mature herring and releasing them into floating net impoundments in which hand-picked kelp (Macrocystis integrifolia) was suspended. The herring were impounded until they spawned on the kelp, which was then removed for packing in salt and delivery to processing plants.

Methods of impoundment and several other aspects of the handling of herring have been examined and evaluated both for the food fishery (Gillis 1979) and for sac roe production (Gillis et al. 1982). Brett and Solmie (1982) and Kreiberg et al. (1982; 1984a, b) have further documented quality control and timing of roe maturation in impounding adult herring, and have identified critical biological and technical problems in capturing, transporting and impounding herring.

Midway through the 1982 spawn-on-kelp season, fishing regulations permitted the use of an alternate fishing technique, "open-ponds", in spawn-on-kelp production. This method differs from the impoundment method in that no fish are impounded and natural spawnings of "wild" herring are

utilized. The product is obtained by suspending Macrocystis from log frames which are then pushed into areas of naturally-spawning, "wild" herring. The spawn-on-kelp fishery is presently conducted throughout the British Columbia coast but is concentrated on the east coast of the Queen Charlotte Islands and north coast of the mainland, which provide high quality Macrocystis.

This report presents information gathered from studies of the 1982 and 1983 spawn-on-kelp fisheries in which impoundments and open-ponds respectively were examined. An evaluation of the fishery, including effects on local herring stocks, is presented.

FISHERY DESCRIPTION

Eleven spawn-on-kelp licensees operate in the Queen Charlotte Islands. During the 1983 fishery, the quotas for these licenses were filled for the first time using the open-pond method. The Queen Charlotte Island fishery occurs in seven general areas (Fig. 1): Skincuttle Inlet, Poole Inlet, lower Juan Perez Sound, Atli Inlet, Sewell Inlet, Cumshewa Inlet and Skidigate Inlet. The remaining 17 licensees, operating on the mainland coast and Vancouver Island, obtained their product with the use of impoundments from the following areas (Fig. 2): Pearl Harbour, Chismore Pass, Hunt Inlet and Kitkatla Inlet in the north coast region; Higgins Pass, Spider Anchorage, Kitasu Bay, and Takush Harbour in the central coast region; Winter Harbour on the west coast of Vancouver Island; Deepwater Bay and Knight Inlet in Johnstone Strait; and Lund, Powell River and Thetis Island in the Strait of Georgia.

The operation of both impoundments and open-ponds varies between license holders; some operators fish as independents while others pool their resources. With some impoundment operations, other fishermen are contracted by licencees to catch the herring, with payment usually in the form of a percentage of the final product. Impoundments often are constructed prior to the fishery and many operators use the same log frames every year, beaching them near the area of operation between seasons. Impoundments typically are located in deep water bays which are sheltered from prevailing winds, and have spawning herring and good quality Macrocystis nearby. Impoundments consist of log frames of varying dimensions from which herring seine web is suspended to form an enclosure; pond frames are anchored to the bottom and/or tied to shore.

Macrocystis is the only kelp species presently used in the Canadian fishery. It is harvested at low tide, usually from herring skiffs. Vessel running time from the area of kelp harvest to the impoundment site ranges from 1 to 8 hours, during which time the kelp is kept moist with seawater. Kelp is suspended in the impoundments tied to weighted lines, and the kelp density used in both open and closed ponds varies between operators.

Herring are seined as close to the impoundments as possible to minimize the possibility of their injury during towing. After a successful set, the seiner and its catch are towed sideways to the impoundment by a second vessel. Two or more sets of herring may be required to fully load an impoundment.

Spawning of herring generally occurs within 1 - 10 days, after which time the spawn-on-kelp is harvested from the lines. The product is usually trimmed with areas of deteriorating kelp or insufficent egg coverage discarded, then salted or brined in regulation size containers (totes) before transport to a processing plant for grading.

Open-pond frames are like those used in impoundments but because there is no seine webbing, they are not as strong or rigid. The methods of harvesting and suspending kelp in open-ponds are identical to those described for the impoundment fishery. Once the wild herring begin to spawn, the operators position the log frames loaded with kelp directly over areas of active spawning, and usually anchor or tie them to shore in deep water bays sheltered from prevailing winds. One to 3 days after spawning, the pond is pulled away from shore and the product harvested in a fashion identical to that described for the impoundment fishery.

METHODS

In 1982, 18 impoundments belonging to 12 licences were monitored in the Queen Charlotte Islands and the north coast: ten in Juan Perez Sound (Section Cove) and Skincuttle Inlet (Fig. 1) and eight in Pearl Harbour (Fig. 2). Two vessels were chartered in 1982, to monitor the fishery between March 6 and April 30. As many impoundment operations as possible were monitored in each area. The 1983 study of the open-pond fishery was conducted in the Queen Charlotte Islands between March 26 and April 16. Ten open-ponds in Sewell Inlet and one open-pond in Cumshewa Inlet were monitored. A Fisheries Guardian cabin located in Selwyn Inlet served as the base of the operation, and the Fisheries Patrol Vessel ARROW POST provided accommodation in Cumshewa Inlet.

Critical to the success of both studies was the maintenance of a good working relationship with the license holders. The sampling and observations described below were conducted so as to have as little impact on the fishery as possible. As a result, all sampling was conducted on an opportunistic basis rather than a systematic one.

IMPOUNDMENT FISHERY

Estimates of the amount of fish in a set were obtained from both the skipper and the crew and were based on their fishing experience. Each stage

in the handling of the fish was monitored and recorded, including fish transport method to the impoundment, the distance between set and impoundment, and towing speed.

Immediately following the release of the fish into the impoundments, and after the product was harvested, herring were sampled for length, sex, total weight, gonad weight and condition. The physical condition of the herring, including percent of scale loss, presence of bruising or open sores and other injuries, was also observed and recorded. Samples of dead herring from the bottom of the ponds were examined whenever possible.

Depending on the licencee's preference, herring samples were collected either with a dip net or a herring jig. This may have resulted in some bias during sampling, particularly for larger herring with the herring jig, but the presence of kelp and lines within the pond made it impossible to use a hand seine or other such device.

To quantify injury, points were assigned to each type of injury: one for a bruise, hemorrhage or ragged fin; two for an open sore or missing fin; and three for a large area of exposed flesh or a mangled snout. The score for each fish was totaled and the average score, or "injury index", calculated for each sample.

Observations of herring swimming behavior and physical condition were obtained either by diving or from the surface.

The extent of spawn deposition on the pond webbing at various depths, measured in number of egg layers, was recorded by divers. Egg samples were taken periodically and examined for fertilization success.

The volume of dead herring which accumulated in the bottom of the ponds was estimated by divers after the harvesting of the product. However, in a few impoundments, this was permitted before herring spawning occurred. The method of estimating volume was site specific. When the ponds were suspended off the bottom, the accumulation of dead herring was generally conical or had a semi-circular cross-section, making the accurate estimation of volume relatively easy. When ponds were sitting on the bottom or the net had torn free from the frame due to the weight of the dead fish, volume was estimated from averages of a number of lengths, widths and depths of the pile of dead fish and was probably less accurate. Herring samples were brought to the surface so that a volume to weight ratio could be determined. The weight of dead fish was calculated from the estimated volume using a conversion factor of 0.6 $t \cdot m^{-3}$. This ratio is the average of five samples taken by divers from the bottom of a pond.

When permitted by pond operators, oceanographic parameters both inside and outside the ponds were measured. These included:

i) temperature and salinity (YSI model #33 temperature-salinity meter).
ii) dissolved oxygen (YSI model #57 dissolved oxygen (D.O.) meter).
iii) ammonia (Hach Ammonium Nitrogen Test Kit - model N1-8).
iv) pH (Hach pH test kit).

The temperature-salinity and D.O. probes were lowered from a float in the center of the impoundment, and measurements were taken at 1-3 m intervals from the surface to the bottom. Similar measurements were taken outside the impoundment. Water samples for pH and ammonia determination were collected by divers. All sampling was carried out during slack tide. On two occasions samples were collected throughout the tidal cycle in order to ascertain what effect tidal currents might have on parameter values.

OPEN-POND FISHERY

Spawn-on-kelp operations using open-ponds in Sewell Inlet and Cumshewa Inlet were directly observed, whereas data on the open-pond fisheries which occurred prior to March 26, 1983, or simultaneously in other areas in the Queen Charlotte Islands were obtained by post-fishery interviews of fishermen and fishery officers.

A minimum of one line and a maximum of two lines of product were sampled from each pond at harvesting. Depending on the operation, product weight was recorded either as it was picked from the lines or after it had been salted and packed. The mean number of egg layers on the kelp was recorded at regular intervals during sampling. Trimmings and discarded (poor quality) product from each sampled line were also collected and weighed. Total product weight in each pond was estimated from the proportion sampled.

To estimate the total tonnage of herring required to produce a given weight of spawn-on-kelp product, three types of information were required: 1) the actual weight of eggs in a given weight of product, 2) the difference in weight between eggs in the roe (unfertilized) and eggs on the kelp (fertilized) since fish eggs normally absorb water immediately after fertilization, 3) the average roe content of the stock in order to calculate the quantity of herring needed to produce a known weight of roe.

To establish the weight of eggs in a given weight of product, product of varying quality, i.e. variable number of layers of eggs, was sampled, weighed, the eggs removed and the kelp weighed again. The effect of fertilization on egg weight was estimated by weighing unfertilized eggs, fertilizing them according to Blaxter (1968) and Alderdice and Velson (1971), allowing them to water-harden, and then reweighing them.

The total number of eggs deposited at each spawning location in Sewell Inlet was estimated by measuring the area covered with spawn and the mean number of eggs per unit area (Haegele et al., 1979). The numbers of spawners at age was calculated from fecundity at age data, age composition, sex ratio, and the estimated number of eggs present (Hourston, 1979). The reproductive potential of the spawning stock which was removed by the open-pond fishery was determined by estimating the number of herring which spawned in the overall inlet and then subtracting that which spawned on the product. A diving survey of egg abundance within Sewell Inlet was conducted on April 16 and 17, 1983 using the method described by Haegele (1981).

After the 1983 open-pond fishery, divers assessed egg survival on trimmed and discarded product at four sites; one in Poole Inlet and three in Sewell Inlet. These were surveyed 12 days and 6 - 9 days respectively after product harvest. Trimmings and 'wild' kelp with spawn were brought to the surface and visually assessed for percent herring egg mortality; dead eggs were easily distinguished by their opaque appearance.

A Macrocystis bed in Dana Inlet, heavily utilized by spawn-on-kelp operators during the 1983 fishery, was surveyed to permit estimation of the total available tonnage of high quality kelp available to the fishery. A spawn-on-kelp fisherman initally assisted with collection of 1 - 3 m lengths of Macrocystis to standardize sampling procedure. The apical meristems were removed and weighed, and the length and total weight of the remaining frond portion was then sampled to estimate the mean weight per meter (W) of Macrocystis. Tonnage (T) utilized by the fishery was determined from the total number of lines (N_v) of kelp taken from the bed by each operator, the mean frond length (L) used on each line and the mean number of fronds (F) on each line:

$$T = (N_1 + N_2 \ldots N_v)\ WLF$$

Processing of spawn-on-kelp product was observed at the B.C. Packers fish processing plant in Masset on April 19, 1983.

RESULTS AND DISCUSSION

POND CONSTRUCTION

All of the ponds used in the impoundment fishery were similar in design. The logs used for frame construction were salvaged from the beach and selected for length, condition and reserve buoyancy. The logs were notched at the ends and lashed together with 12-16 mm diameter wire cable or boom chain. Once constructed, the frames were anchored in deep water areas sheltered from prevailing winds. Table 1 gives the maximum dimension and volume of the impoundments observed.

Webbing is generally 25 to 35 mm stretched, black, knotted herring seine web. There are three basic impoundment types (Fig. 3): shallow impoundments where the bottom of the webbing is usually 5 - 8 m deep; deep impoundments where the bottom of the webbing is greater than 10 m deep; and, grounded impoundments, where the pond webbing is allowed to sit on the bottom, which may be as deep as 21 m.

Shallow impoundments are constructed of three or more 4.6 m web strips sewn together longitudinaly into a single panel of varying lengths to form the bottom of the enclosure. An additional strip of seine web is sewn around the perimeter of this larger bottom panel to form the sides. The tops

of the side panels are then nailed to the inside of the logs. One portion of the net, usually at a corner, has an additional section of seine web sewn in to form the impoundment gate, which is dropped to form an opening in the enclosure through which the herring swim from the seine net. Gates varied in size between ponds from 2.4 to 5.5 m in width and 0.9 to 1.8 m in depth. Rocks were suspended from the frame around the inside of the impoundments to help maintain the rectangular shape and maximize impoundment volume.

With deep impoundments, web strips are sewn into a single panel of varying depths and lengths depending on the log frame dimensions, and 12 mm polypropylene line is usually laced into the bottom and top edges of the net panel. The top edge of the panel is then nailed to the log frame and the ends of the panel laced together where they meet. The bottom edges of the panel are then "pursed" with a line previously secured to the edge of the frame, to form the enclosure bottom. This potential opening at the bottom of the impoundment facilitates the removal of acccumulated dead fish and trimmed product at the end of the operation. Some operators also lace lead line into the perimeter of the seine web to keep the sides of the enclosure hanging vertically. Gates in deep impoundments varied in size between 4.9-9.7 m in length and 1.8-4.6 m in depth.

Grounded impoundments were identical to deep impoundments in construction except that a large area of the enclosure bottom rests permanently on the bottom while the log frame moves up and down with the tide. This results in a great deal of slack net during low tides and an irregular pond shape, along with the formation of temporarily isolated enclosure pockets.

Logs in open-pond frames (Fig. 4) are often notched at the ends and lashed together with 16-25 mm diameter rope or boom chain. The open-pond fishery is relatively mobile with fishermen moving their log-frames to areas of active spawning. Some operators have a number of ponds placed in traditional herring spawning areas, while others have 2 to 4 ponds which they tow from area to area. To facilitate their mobility, some ponds are constructed so that a boom chain can be dropped from one corner and the pond pulled part. This allows the logs to be towed in a narrow line rather than as a square or rectangle, thus permitting greater speed and reducing travel time. When reconstructed, the frames are reinforced at each corner with cross-braces and are anchored in sheltered areas near an anticipated spawning. Table 1 presents the dimensions of the open-pond frames observed.

CAPTURE, TOWING AND TRANSFER OF HERRING TO IMPOUNDMENTS

Table 2 summarizes observations made concerning the capture, towing and transfer of herring to the impoundments. This aspect of the operation is well described by Gillis (1979) and by Gillis *et al.* (1982). The procedures described in these two reports closely resemble what we observed during spawn-on-kelp operations.

In general, scale loss, injury and bruising of the herring was minimal during the observed operations. This was also reported by Gillis et al. (1982) even though the average towing distances (5.6 km) and times (10.7 hr) they observed were greater than those recorded in the present study. Average tow rates were 0.52 and 0.56 $km \cdot hr^{-1}$ in each study respectively.

A significant amount of scaling and bruising occurred in two of the tows: set 1 of pond 1, where 63 t of fish were towed for 5.5 hours over 5.6 km, and set 2 of pond 11, when the towed seine net became entangled in a pond mooring cable.

Generally, little damage to the fish resulted from transfer from the seine net to the impoundment. On several occasions, some scale loss and brusing did occur due to either or both of the following reasons: when shallow gates were used and a large volume of fish were in the seine net,or when the seine net was dried up too quickly and the fish were overcrowded.

LOADING DENSITY

Table 3 gives information on loading densities observed in the impoundments. As previously stated, the impoundment volume estimates were maximum values and do not account for ballooning in of the side panels. In addition, estimates of seined tonnage are probably conservative. Therefore, the loading densities presented should be considered as minimum estimates. The average loading density observed was 41.7 $kg \cdot m^{-3}$ and with one exception all of the observed densities were equal to or greater than 16.7 $kg \cdot m^{-3}$. Gillis et al. (1982) found that herring should not be impounded at loading densities exceeding 16.7 $kg \cdot m^{-3}$ (1.0 $lb \cdot ft^{-3}$) for more than four or five days and that densities greater than 25 $kg \cdot m^{-3}$ should be avoided at all times. Brett and Solmie (1982) found that mortality was highly density-dependent and concluded that the density for longer term holding should be no more than 8.4 $kg \cdot m^{-3}$. However, in subsequent work (Kreiberg et al. 1982, 1984b) clear evidence of density-dependent mortality could not be demonstrated and so the prevailing opinion is that while there is some correlation, it is significantly influenced by holding-time. For impoundings of <4 weeks, herring densities up to 16 $kg \cdot m^{-3}$ are acceptable. The probable cause of mortality in impoundments is density-related stress; the pathological cause is unknown. As can be seen from Table 3, loading densities in spawn-on-kelp ponds often greatly exceeded the values given above. This is probably the main factor leading to herring injury and mortality in spawn-on-kelp impoundments.

Fish from Skincuttle (213.6 mm average length, both sexes combined; different sample dates or locations (s)=4, n = 430) were larger than fish seined in Section Cove (208.5 mm; s = 12; n = 1365) which in turn were larger than the fish from Pearl Harbour (193.6 mm; s = 13; n = 996) and Kitkatla (189.8 mm; s = 3; n = 243). Within each area, the average length of males and females varied little between samples, probably because fish were from the same school or cohort. This was especially true in Section Cove where herring remained in the bay for a number of days and the operators repeatedly took sets from the same group of fish. The sex ratio (% female) varied markedly,

even between sets taken near each other at the same time. The differences in sex ratio resulted in large differences in apparent roe content (expressed as the percentage which the weight of the roe constituted of the total weight of the sample). Among females, the roe content at capture and before spawning was relatively constant at 24-25%.

From samples collected after spawning and of dead fish in the impov ents, no differences in the mortality rates between sexes or size clas.es were evident. The percentage of females which spawned was low in the majority of samples.

Injuries (Table 4) included bruising on the operculum and snout and other areas of the body, hemorrhaging at the base of the fins and deterioration of the fins. More serious injuries included open sores on the body and snout, broken and mangled snout and lower jaw and almost complete wearing away of dorsal and caudal fins. Little evidence was found of subcutaneous hemorrhaging of capillaries which was described by Brett and Solmie (1982). Scale loss is more difficult to quantify since handling during sampling itself results in additional scale loss. However, scale loss (Table 4) is positively correlated with the injury index. Both these values were low when the fish were first placed in the impoundments but increased after a few days of holding.

There was a significant relationship between loading density and injury rate (Fig. 5) (r^2 = .525; P = .008), but possible error in both estimation of loading density and injury quantification makes it difficult to draw precise conclusions.

MORTALITY

The estimated total mortality and mortality expressed as a percentage of the fish initially placed in the impoundment are given in Table 5. In Section Cove, the total weight of dead fish was estimated as 261 t or 29% of the inital weight whereas in Pearl Harbour, it was estimated to be 264 t or 40% of the inital weight. Correlation of net percent mortality with loading rate was poor, perhaps because of estimation errors associated with measuring these two variables. In Pearl Harbour especially, loading densities and percent mortalities were difficult to estimate.

In shallow impoundments, the weight of dead fish was frequently sufficient to pull much of the log frame underwater. In some instances, the impoundment split open spilling the dead fish to the bottom below the log frame. Release of four or five nails holding the impoundment net sometimes resulted in the entire net breaking away from the log frame; the net pulling away from the initial break like a zipper until the entire net was on the sea bottom. A large proportion of released fish were injured but mortality rate of injured fish following release is unknown.

SPAWN DEPOSITION ON NETS

Herring normally spawned lightly on the top meter of web immediately after being placed in the impoundment, even if there was no active spawning on the kelp. The amount of spawn on the web increased as spawning progressed in the impoundment and often extended to the bottom of the impoundment. The number of layers and area of the net covered decreased with depth and was usually heaviest in the upper 3 - 5 meters of the net. In this depth range the portion of the net covered with spawn reached 80 - 90% and as many as 8 - 10 layers of eggs. In addition to fish inside the impoundment, herring outside the impoundment were often observed spawning on the outer net surface.

Fertilization rate appeared to be about 100%. Development and hatching success were also high, except near the bottom of the impoundment where eggs in direct contact with dead fish all died.

WATER CHARACTERISTICS

Temperature, salinity, D.O., pH and ammonia levels inside the ponds varied little from those recorded outside, although the D.O. was slightly lower inside some impoundments. This seemed to occurr when fish were first loaded in the impoundment and were very active. The lowest D.O. value observed was 6.5 ppm at a depth of 5 m while outside the impoundment at a similar depth D.O. was 8.5 ppm. D.O. values were normally well above 7.5 ppm at all depths in impoundments, and being well above half-saturation levels, it is unlikely that D.O. contributed significantly to observed mortalities.

Salinity varied between 30-31 ppt and temperature varied between 7.0-8°C in all impoundments, while pH was always in the vicinity of 8.0-8.5. In most of the samples analyzed, the ammonia concentration was negligible, with the highest value recorded being 1.0 ppm.

KELP UTILIZATION AND SUSPENSION

Young, immature fronds at the growing tip, or meristems, of Macrocystis (Fig. 6) are thin, translucent and exude polysaccharides which prevent secure attachment of roe (Whyte, 1979), and they are therefore discarded before the kelp is suspended. Fishermen collect Macrocystis that is dark in colour and has large fronds. Minimum blade dimensions for number one product are 35.6 by 10.2 cm. Older fronds from below 3 m depth are frequently ragged and epiphytized and were not collected. Macrocystis fronds are cut into 1 - 3 m lengths and are usually tied onto lines as they are harvested (Fig. 7). Lines are prepared before the fishery and consist of halibut long line to which loops of nylon twine, or "beckets", are attached at 20 to 41 cm intervals.

When the skiffs are fully loaded with kelp, they are immediately taken to the log frames. Care is taken while transporting the kelp to prevent desiccation or damage, and the kelp is kept moist with seawater and covered with plastic if it is raining.

At the frames, the lines with attached Macrocystis are fastened to the logs with a spacing of 31 to 152 cm. The lines are usually weighted with rocks or lead to keep the Macrocystis submerged. After 8 to 10 days the kelp blades begin to rot from the tip and outside edges. Once spawn has been deposited on the kelp, deterioration is more rapid, making it important for the kelp to be of good quality when spawning occurs.

During spawning, the lines being to sink due to the weight of the eggs. By the time 6 to 12 layers of eggs are deposited on the kelp, one line of kelp weighs between 180 and 635 kg and the middle of each line will have sunk 3 to 5 m. This can cause two problems:

1) because kelp fronds are 1 to 3 m long, 3-5 fronds in the middle of each line may rest on the bottom during low water and be ruined by sediment.

2) the center 5-10 fronds on each line may become entangled, causing incomplete and/or uneven egg coverage because of reduced access by herring to each blade.

Approximately 3 t of product was discarded due to these problems in Sewell Inlet by operators using open-ponds. To minimize this loss lines were sometimes tightened within the ponds as spawning occurred or spacing between fronds sufficient to prevent entanglement was used. Tables 6 and 7 summarize kelp collection and suspension in the observed impoundments and open-ponds.

POSITIONING OF OPEN-PONDS

Unlike the impoundment fishery, where the fish are towed to a pond, the open-pond fishery requires the ponds to be positioned over the spawning herring. This is the most critical stage of the open-pond fishery. Operators must place the ponds both close enough to shore so that the suspended kelp is close to natural, attached vegetation yet so it remains off the bottom at low tide and in areas sheltered from prevailing weather.

In exposed areas, substrate type is an important consideration in the positioning of open-ponds since although ponds may be anchored in sheltered areas, wave and/or swell refraction may stir up mud or fine sand. Once suspended in the water, mud and sand become readily attached to the spawn-on-kelp product, and the product becomes unmarketable. Fresh water runoff, especially in areas of active logging, can also contain sediment; operators prefer not to locate near stream outlets.

Because the positioning of open-ponds is dependent on the location of active spawning and the availability of useable shoreline, operators frequently have to place their ponds in less than ideal sites. As a result considerable product had to be discarded from open-ponds during the 1983

fishery. At Alder Island and Huxley Island in Juan Perez Sound (Fig. 1) approximately 255 lines of product, estimated to weigh between 46-162 t, were stripped from 9 open-ponds due to their permeation with sand or alluvial silt. During the 1983 fishery conducted in Sewell Inlet, at least 2.4 t of product was lost from 3 open-ponds due to contamination with alluvial silt.

None of the closed pond operations lost product due to sediment contamination, as this can be avoided by locating impoundments at suitable sites.

PRODUCT HARVEST

Spawn-on-kelp product is graded both by the number of egg layers and the dimensions and condition of the kelp. A minimum of three, evenly distributed layers of eggs on each side of a healthy blade (minimum dimension - 35.5 x 10.2 cm) is considered top grade (number one). Harvesting occurs when the pond operator is satisfied that the product is of sufficient quality, or when it appears that the product is beginning to deteriorate. Harvesting generally occurs 4-6 hr after spawning to allow for washing off of the adhesive milt on the product. Before harvesting, the impoundment gate is opened and the herring are allowed to escape. In the case of the open-pond fishery, the entire pond frame is often pulled from the beach into deeper water and anchored.

Most operators place a herring skiff inside the impoundment or open-pond frame to harvest the product. The skiff is moved slowly along each kelp line while the kelp stipes are removed. The blades are removed from the stipes and stacked in containers if they appear to be of good quality. The rest is discarded. Some operators use a clothes-line type system to harvest the product directly onto the support vessel. This method eliminates one entire step of product handling.

Most of the operators trim their product before it is packed (Fig. 8). Each blade is trimmed at the ends and anywhere else where the kelp is ragged or where there is insufficient egg coverage. There is a tendency for the blade tip to deteriorate before other portions of the blade.

Some groups of pooled permit holders do not trim their product. Complete blades of product are packed directly into the totes. Although a higher percentage of number one product results from trimming, it is felt by some pooled operators that trimming is not cost effective. One pool of three permit holders estimated that the operating costs of trimming 24 t of product were equal to or greater than the increased value of trimmed product.

After picking, the blades are packed into totes, salted, and transported to the processing plant. Approximately 180 to 225 kg of salt are used for a large tote (1.07 m square, 60 cm deep). Some operators add 100 percent brine to the totes in addition to salt in order to guarantee preservation of all product. Each permit holder harvests approximately 14.5 large totes.

During the 1982 and 1983 fisheries, all the operators around the mainland islands filled their permits using impoundments. In the Queen Charlotte Islands, both fishery techniques were used in 1982 but only open-ponds were used in 1983. Little product was obtained from the 10 impoundments operating in Juan Perez Sound during the 1982 fishery. The failure of the fish to spawn in these impoundments does not appear to be related to any obvious factor, and the total tonnage of fish in each impoundment was more than sufficient to provide the desired tonnage of product. This lack of spawning within the observed impoundments during the 1982 fishery was highly irregular.

OPEN-POND PRODUCTION

Table 8 lists the approximate number of totes of product harvested from the major areas fished in the Queen Charlotte Islands during the 1983 fishery. Interviewed fishermen stated that one large tote yields between 544 and 635 kg of product. Based on the number of totes, 11 percent of the total spawn-on-kelp product harvested in the Queen Charlotte Islands was taken from Poole Inlet, 27% from Alder Island, 9% from Huxley Island, and 49% from Sewell Inlet.

From the nine open-ponds in Sewell Inlet operated by eight permit holders, an estimated 55,175 kg (78 totes) of product was collected (Table 9): 81% was processed; 11% was trimmed and 8% was discarded due to excessive silt.

QUANTITY OF HERRING REQUIRED TO PRODUCE PRODUCT

With number one product (6+ layers of eggs, 3+ per side), kelp percentage by weight averaged 10.3% (S.D.=3.9) (Table 10) and varied little ($\bar{x}$=12%, S.D.=4.2) regardless of the number of layers of eggs present (Fig. 9). Eggs gained an average 54% in weight on fertilization, and the prefertilization weight averaged 65% of the post fertilization weight (Table 11). Female roe content varied between samples (Table 12). With a population roe yield of 14.8% in Selwyn Inlet on March 28, 1983, the weight of herring required to produce 55 t of product in Sewell Inlet was estimated to be 217 t (Table 13).

The processed product represented the reproductive potential of an estimated 177 t of herring. The 14.8% population roe yield of herring tested in Selwyn Inlet was relatively high and with a more usual yield of 12% (Table 12), the tonnage of herring required to produce this product weight would increase by 23% to about 267 t.

EGG SURVIVAL ON TRIMMED OR DISCARDED PRODUCT

To accurately estimate the reproductive potential of herring removed by the spawn-on-kelp fishery, the survival of eggs on trimmed and discarded product must be considered. If survival is low, then the quantity of herring needed to produce the total product weight in each operation should be determined. If egg survival, however, approaches that of eggs on natural vegetation, then only the amount of herring needed to produce processed product need be considered.

Diver surveys of open-ponding sites in Sewell and Poole Inlets in 1983 indicated that the survival of eggs on trimmed and discarded product equaled that on natural vegetation. Egg survival in Sewell Inlet was roughly 95 to 97 percent, and 70 to 80 percent within the two surveyed areas at Poole Inlet. The lower survival in Poole Inlet may have been caused by low oxygen levels as the flushing rate at that specific spawning location appeared low and natural spawning in the bay was heavy.

Based on these qualitative observations, it appears that the eggs attached to trimmed and discarded spawn-on-kelp product are not lost to the fishery and that only the harvested and processed spawn-on-kelp weight should be considered in estimating the lost reproductive potential. Based on these estimates, one permit (7.26 t) in Sewell Inlet required roughly 28.6 t of herring.

ESTIMATION OF SPAWN ABUNDANCE

To estimate the reproductive component of the overall spawning stock removed by the spawn-on-kelp fishery, the total number of spawning herring was estimated from spawn deposition. Spawn locations during the 1983 fishery in Selwyn and Sewell Inlets were extensive, but only the spawnings in the area of the spawn-on-kelp fishery (85% of the total) were surveyed by divers. Total number of eggs deposited within the survey area and estimated weight of fish which spawned on natural vegetation are presented in Table 14. From the number of fish at age, sex ratio data from pre-fishery samples and fecundity at age data (Hourston and Schweigert, 1980), it was estimated that 1 t of herring produced 1.27×10^8 eggs in Sewell Inlet. This figure was used to convert the estimated total number of eggs deposited in the survey area to tonnes of spawners, and it was estimated that 2,228 t of herring spawned on natural vegetation within the area of the spawn-on-kelp fishery in Sewell Inlet. The spawn-on-kelp fishery thus removed about 8% of the reproductive potential of the exploited population.

KELP BED SAMPLING INFORMATION

A provincial harvesting license allows each fisherman to manually harvest individual stipes of Macrocystis from areas of their choice. Because

the harvested amount of Macrocystis used by the fishery represents a small percentage of the total available biomass, no quotas were set.

During the 1982 and 1983 fisheries, a number of operators expressed concern over the lack of good quality Macrocystis in the Queen Charlotte Islands. Although Macrocystis is abundant on the east coast of Moresby Island, only a portion of it is suitable for the spawn-on-kelp fishery. The kelp blades should be robust, dark in colour, large bladed and free of epiphytes. It was generally felt by the fishermen that the amount of useable Macrocystis available on the east coast of Moresby Island was declining, and that an increasing amount of time and effort was being spent searching for good quality kelp. This apparent decline of useable Macrocystis was probably unrelated to commercial harvesting since studies indicate that the vegetative growth of Macrocystis is sufficient to recover from harvesting (L.M. Coon, pers. comm.). It is more likely that environmental conditions during the winter months (i.e. storms) are affecting annual availability of high quality kelp.

One of the Macrocystis beds most utilized by licensees operating in Sewell Inlet during the 1983 fishery was located in Dana Inlet (Fig. 1). Although there was roughly 7 km of Macrocystis along both shores of Dana Inlet, only one bed measuring 500 m by 20 m was used by fishermen. The rest of the kelp in this inlet was considered unuseable. The mean weight of Macrocystis in the bed was estimated to be 0.88 $kg \cdot m^{-1}$, and the total harvest was 4939 kg.

PROCESSING INFORMATION

Methods of processing spawn-on-kelp product are similar between all processors. At a plant, the tote containing the product is drained and filled with 100 percent brine. Immediately prior to processing, the totes are drained again. Individual blades of product are removed from the totes and rinsed in salt water to remove any exudate and excess salt. The blades are then stacked in trays and allowed to drain for approximately one hour, after which the product is graded by individuals who have been trained by an experienced technician. Portions of each blade which are ragged, rotten or without eggs are trimmed by graders so that the blade meets the standards of the highest possible grade.

Rotten kelp, kelp without roe and product which has been contaminated with sand, silt or oil is generally unacceptable. The criteria for number one kelp is consistent between buyers but for lower grades, each buyer has different grading standards.

Graded product is packed and salted in 15.4 kg lots in standard herring buckets with approximately 15.4 kg of product per bucket. Each bucket is filled with 100 percent brine, sealed and stored at 5°C until shipping. If the landed weight of product for a licence exceeds 7.26 t then the excess product is released to the Crown to be auctioned off at a later date. The overage weight retained by the Crown is prorated according to the total product weight within each grade.

SUMMARY

Little herring damage or mortality is normally associated with capture, towing and transfer operations as long as sufficient care is exercised. Specifically to be avoided are high towing speeds, small gate sizes and excessive drying up of the set. In almost all cases, the operators observed were very conscientious and careful and the majority of fish arrived in the pond in excellent condition. Egg deposition on impoundment webbing was extensive in many impoundments. The hatching success of the spawn on the net was high if the net was left submerged. Water quality, within and outside impoundments was similar and it is unlikely that this caused the observed fish mortality. The main cause of mortality appears to be high loading densities (41.5 $kg \cdot m^{-3}$ average). Fish observed initially to be in good condition were in poor condition after a week and large volumes of dead fish had accumulated on impoundment bottoms. Behavioral observations also support over-crowding: boiling at the impoundment surface and near the webbing and the absence of cohesive schooling indicated that significant overcrowding was occurring. In most cases, even within impoundments where sufficient spawning occurred prior to harvesting, the proportion of unspawned females was high among live and dead fish.

The open-pond spawn-on-kelp fishery is more mobile and widespread than the impoundment fishery. The use of open-ponds offers some distinct advantages over the use of impoundments. These advantages include:

1) no requirement to handle or impound the fish, thus eliminating problems with injury and mortality.

2) reduced equipment as there is no need for a net enclosure.

3) less removal of herring reproductive potential. In a natural spawning, almost all of the fish spawn and few die, whereas with impounded herring, many fish may die or fail to spawn.

However, since open-ponding occurs close to shore and frequently in semi-exposed or estuarine areas, considerable potential spawn-on-kelp product may be lost due to contamination by sediment. Operators can minimize contamination and improve product quality by insuring sufficient spacing between suspended Macrocystis frond in the ponds; tightening the kelp lines as spawning occurs, and positioning pond frames in sheltered areas over suitable substrate away from river and stream mouths.

With open-ponding, the survival of eggs deposited on trimmed and discarded product appeared equivalent to that of eggs deposited on natural vegetation. Therefore only the processed product should be considered when determining the impact of both open-pond and impoundment fisheries on the reproductive potential of local spawning stocks of herring. It was estimated that during the 1983 fishery, 177 t of herring were required to produce 45 t of harvested product using open-ponds in Sewell Inlet (Queen Chalrotte Islands). This represents 8% of the estimated 2,450 t of herring which spawned in the area. Based on these estimates, one spawn-on-kelp licencee using open-ponds removed the reproductive capacity of about 28.6 t of herring

(14.8% roe-yield). With a 12% roe yield, 35.2 t of herring would have been required to satisfy one licencee quota.

With impoundments, 45.5 to 63.5 t of herring is used to produce 7.26 t of product, but the actual removal of spawners can be less if loading densities are maintained at a 24.9 $kg \cdot m^{-3}$ level and the impoundment webbing is left intact until after the deposited eggs hatch. However, this does not account for those herring which died during impoundment or later due to injury, and their reproductive potential lost for future years.

Many spawn-on-kelp operators in the Queen Charlotte Islands expressed concern over the decreasing availability of good quality Macrocystis. Although Macrocystis is abundant, only a portion of it is accessible and of suitable quality for the spawn-on-kelp fishery.

Pooling of manpower, resources and product is common in the open-pond fishery. Because herring spawnings are frequently isolated, both temporally and spatially, the efficiency of the fishery is enhanced if a number of operators combine their efforts. This allows better access by individual operators to all of the major spawnings.

Due to the coastal topography and the relative long presence of spawning herring, open-ponds are appropriate in the Queen Charlotte Islands. The steep, rocky coastline means open-ponds can usually be anchored in sheltered areas over a natural spawning substrate. If the product quota is not obtained from one area, the entire operation can be quickly moved to the next spawning.

However, despite the apparent advantages of open-ponds, many areas of the coast are unsuitable for their use. Impoundments are better suited for the spawn-on-kelp fishery in areas where herring spawn in shallow and/or exposed areas; and in areas where natural spawnings take place over a short time period. When herring are impounded at a moderate density and care is taken during capture, towing and transfer, the use of impoundments can be a biologically sound and efficient method of spawn-on-kelp production.

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Table 1. Summary of observed impoundment and open-pond dimensions and volumes.

Area	Pond Number	Dimensions (m) Length	Width	Depth	Volume m^3	Volume $10^{-3} ft^3$
A. Impoundments						
Section Cove	1	24.2	18.2	4.5	1980	72.0
	2	24.2	18.2	4.5	1980	72.0
	3	24.2	18.2	4.5	1980	72.0
	4	24.2	18.2	4.5	1980	72.0
	5	21.2	18.2	4.5	1740	63.0
	6	24.2	18.2	4.5	1980	72.0
	7	21.2	18.2	4.5	1740	63.0
	8	16.5	10.5	6.0	1040	38.5
	9	9.1	9.1	7.6	630	22.5
Jedway Bay	10	circular diameter - 82.4 depth - 10.7			5780	203.0
Pearl Harbor	11	26.5	16.2	13.8	5920	212.0
	12	17.5	13.8	13.8	3380	123.0
	13	28.5	13.0	13.7	5080	182.0
	14	16.0	13.0	14.1	2930	107.0
	15	20.7	18.6	14.5	5580	199.0
	16	21.0	14.7	13.9	4291	156.0
	17	19.2	14.1	14.0	3790	136.0
	18	17.8	10.5	5.2	972	35.1
Kitkatla Inlet	19	15.8	10.4	10.0	1640	58.3
	20	14.0	10.4	13.0	1890	67.3
	21	16.5	10.5	13.0	2250	81.3
B. Open-ponds						
	1	19.5	19.9			
	2	N/A	N/A			
	3	16.5	17.7			
	4	17.5	18.0			
	5	19.4	19.5			
	6	18.0	17.5			
	7	19.7	20.4			
	8	17.7	19.0			
	9	16.5	17.7			
	10	15.2	13.5			
	11	19.5	17.9			

Table 2. Summary of herring set and towing information. A. Queen Charlotte Islands. B. North Coast mainland.

Area	Pond Number	Set Number	Date	Time of set (PST)	Towing Time (hr)	Transfer Time (hr)	Total Handling Time (hr)	Tow Distance (km)	Set (t)	Transfer to Pond (t)	Cumulative Total in Pond (t)
A. Section Cove	1	1	Mar. 15	1300	5.5	1.5	7.0	5.6	63	63	
		2	18	0700	2.0	2.0	4.0	0.9	36	36	
		3	19	0700	3.5	2.0	5.5	0.9	100	9	108
	2	1	Mar. 15	1630	1.0	1.5	2.5	0.9	36	36	
		2	18	0700	1.5	1.5	3.0	0.9	82	82	118
	3	1	Mar. 19	0700	3.5	2.0	5.5	0.9	109	100	100
	4	1	Mar. 19	0700	5.5	1.5	7.0	0.9	54	54	
		2	20	1030	2.0	1.0	3.0	0.9	36	36	90
	5	1	Mar. 19	0650	1.2	1.0	2.2	0.6	45	45	
		2	19	0920	1.3	0.8	2.1	0.6	32	32	
		3	20	0710	1.6	1.5	3.1	0.6	109	54	131
	6	1	Mar. 20	0710	1.5	5.5	7.0	0.6	109	54	
		2	21	--	1.8	1.0	2.8	0.6	36	36	90
	7	1	Mar. 15	1600	1.0	1.5	2.5	1.3	36	36	
		2	18	0800	0.7	1.3	2.0	-	91	91	127
	8	1	Mar. 19	1100	0.3	2.5	2.8	0.4	27	18	
		2	20	0735	1.5	1.1	2.6	0.2	54	32	50
	9	1	Mar. 16	1720	0.8	1.7	2.5	0.2	14	14	
		2	17	1010	0.5	1.0	1.5	0.2	91	41	
		3	20	0735	1.5	2.7	4.2	0.2	54	9	64
											(released Mar. 23)
		4	24						18	18	18
Jedway Bay	10	1-4	Mar. 20-22					2.4			100
											TOTAL 832

Table 2 (cont'd)

Area	Pond Number	Set Number	Date	Time of set (PST)	Towing Time (hr)	Transfer Time Time (hr)	Total Handling Time (hr)	Tow Distance (km)	Set (t)	Transfer to Pond (t)	Cumulative Total in Pond (t)
B. Pearl Harbor	11	1	Mar. 25	0735	1.5	1.5	3.0	0.9	91	91	
		2	26	0700	1.5	1.0	2.5	0.9	73	54	145
	12	1	Mar. 28	1730	1.0	1.5	2.5	0.4	181	91	91
	13	1	Mar. 28	0630	1.0	1.5	2.5	0.2	181	181	181
	14	1	Mar. 28	1535					36	36	36
	15	1	Mar. 28	0630	1.5	2.0	3.5	0.9	272	91	91
	16	1	Mar. 29	1410	1.5	1.5	3.0	0.9	91	73	73
	17	1	Mar. 28	0030	3.0	1.1	4.1	0.9	317	100	100
	18	1	Mar. 30		1.5	1.5	3.0	0.4	18	18	18
											TOTAL 735

Table 3. Loading densities in spawn-on-kelp impoundments. A. Queen Charlotte Islands. B. North Coast mainland.

Area	Pond Number	Estimated Load		Pond Volume		Loading Density	
		10-3 kg	10-3 lb	m--3	10-3 ft--3	kg.m-3	lb ft-3
A. Section Cove	1	109	240	1980	72.0	55	3.3
	2	118	260	1980	72.0	60	3.6
	3	100	220	1980	72.0	51	3.1
	4	91	200	1980	72.0	46	2.8
	5	132	290	1740	63.0	76	4.6
	6	91	200	1980	72.0	46	2.8
	7	127	280	1740	63.0	73	4.4
	8	50	110	1040	38.5	48	2.9
	9	64	140	630	22.5	102	6.2
Skincuttle	10	100	220	5780	203.0	17	1.1
B. Pearl Harbor	11	145	320	5920	212.0	24	1.5
	12	91	200	3380	123.0	27	1.6
	13	181	400	5080	182.0	36	2.2
	14	36	80	2930	107.0	12	0.7
	15	91	200	5580	199.0	16	1.0
	16	73	160	4291	156.0	17	1.0
	17	100	220	3790	136.0	26	1.6
	18	18	40	972	35.1	19	1.1

Table 4. Summary of scale loss and injury information from fish collected from impoundments (1982).

Pond Number	Sample Date	Residence time (days)	Mean % Scale loss	Injury Index	Initial Loading Density ($kg \cdot m^{-3}$)
2	Mar. 18	0	<10	0.0	
3	28	9	42	4.3	51.7
4	28	9	31	3.8	46.7
5	Apr. 2	14	20	3.6	76.7
6	Mar. 29	9	28	3.7	46.7
7	18	0	<10	0.0	
	25	7	18	3.1	73.4
	27	dead sample	48	6.0	
8	30	10	18	5.1	48.3
10	Mar. 22	0	<10	0.0	
	26	4	-	2.3	
	30	8	54	2.6	18.3
	23	32	30	1.1	
11	Mar. 25	0	10	0.2	
	26	1	29	1.7	
	Apr. 6	12	45	1.1	25.0
12	Mar. 28	0	81	-	
13	Mar. 28	0	20	-	
	Apr. 6	9	41	1.8	36.7
14	Mar. 28	0	20	-	
	Apr. 4	7	23	0.4	11.7
15	Mar. 28	0	28	-	
	Apr. 5	8	31	1.0	16.7
16	Mar. 30	1	35	-	
17	Mar. 28	0	12	-	
	Apr. 5	8	66	1.4	16.7

Table 5. Mortality estimates from spawn-on-kelp impoundment in 1982. A. Queen Charlotte Islands. B. North Coast mainland.

Area	Pond Number	Time from Inital Loading (d)	Dead herring: Volume (m^{-3})	Dead herring: Weight [1] (t)	Initial quantity (t)	% Mortality	Initial loading density (kg m^{-3})
A. Section Cove	1	8	54	32	109	29	55
	2	8	93	56	118	48	60
	3	9	45	27	100	27	51
	4	9	17	10	91	11	46
	5	10	18	11	132	8	76
		13	23	14	132	11	76
	6	9	67	40	91	44	46
		12	49	29	91	32	46
	7	7	32	19	127	15	73
		11	86	52	127	41	73
	8	10	42	25	50	50	48
	9	13	27	16	82	20	102
Total			426	261	900	29	
Skincuttle	10	10	8	5	100	5	17
		13	15	9	100	9	17
Total			23	14	200	14	
B. Pearl Harbor	11	1	0	-	145	0	24
		13	105	63	145	43	24
	12	9	5	3	91	3	27
	13	2	0	-	181	0	36
		10	188	113	181	62	36
	14	10	5	3	36	8	12
	15	2	0	-	91	0	16
	17	10	137	82	100	82	26
	18	7	0	-	18	0	19
Total			440	264	662	40	

[1] calculated from volume x .60 $t \cdot m^{-3}$.

Table 6. Summary of observations of kelp collection and suspension in the observed impoundments.

Area	Pond Number	Distance Transported (km)	Number of Lines	Line Length (m)	Spacing Between Lines (cm)	Frond Length (m)	Spacing Between Fronds (cm)
A. Q.C.I.							
Section Cove	1	6.5	45	18.3	30-41	1.8	30-41
	2	6.5	45	18.3	30-41	1.8	30-41
	3	6.5	45	18.3	30-41	1.8	30-41
	4	6.5	45	18.3	30-41	1.8	30-41
	5	6.5	33	18.3	30-41	.9-1.8	30-46
	6	6.5	30	18.3	30-41	.9-1.8	30-46
	7	6.5	45	18.3	30-41	.9-1.8	30-46
	8	6.5	14	15.2	76	1.8	30-41
	9	6.5	18	9.2	46	1.8	30-41
Jedway Bay	10	6.5	10	13.7	127-152	1.8-3.6	30-41
B. North Coast							
Pearl Harbor	11	37.1	30	22.0	46-51	4.6	20-30
	12	27.8	12	22.0	102	3.6	20
	13	27.8	29	13.4	91	3.6	20
	14	27.8	18	12.2	84	3.6	20-25
	15	27.8	12	18.3	123	3.6	25
	16	27.8	10	13.7	123	3.6	25
	17	37.1	21	12.8	91	1.8	30
	18	37.1	18	12.8	91	1.8	20-30

Table 7. Summary of observations of kelp collection and suspension in the observed open-ponds.

Pond	Number of Lines	Line Length (m)	Mean No. Beckets Per line	Frond Length (m)	Spacing Between Fronds (cm)
1	23	N/A	45	1.3	-
3	14	16.5	28	1.5	58
4	18	16.6	28	1.4	59
5	17	18.3	55	1.7	33
6	15	16.6	32	1.3	52
7	22	N/A	48	1.6	-
8	14	18.3	55	2.5	33
9	7.5	16.5	28	1.5	59
10	15	18.3	55	2.5	33
11	20	18.3	63	2.8	29

Table 8. Summary of the 1983 open-pond production in the Queen Charlotte Islands. The total number of ponds represents the cumulative total; many ponds were used repetitively.

Area	Dates Fished	Number of Ponds	Number of Totes Harvested	Percent of Total Harvest
Skincuttle Inlet				
Jedway Bay	Mar. 4-11	1	0	
	Mar. 27-28	2	0	
Houston Inlet	Mar. 27-28	2	0	
Poole Inlet	Mar. 12-18	12	18	11
Juan Perez Sound				
Alder Island	Mar. 18-23	12	44	27
Huxley Island	Mar. 27-30	3	0	
	Apr. 1- 6	5	15	9
Section Cove	Mar. 21-24	2	0	
Selwyn Inlet				
Sewell Inlet	Apr. 5-12	10	78	49
Cumshewa Inlet				
Aero Camp	Mar. 28-11	1	6	4
TOTALS		50	161	100

Table 9. Summary of spawn-on-kelp production by open pond. "Trim" denotes poor quality product which has been cut from individual blades. "Released" denotes entire fronds of poor quality product which have been discarded.

Pond No.	Total Product Weight (kg)	Trim Weight (kg)	Released Weight (kg)	Total Harvested Weight (kg)	No. of Totes
A. Sewell Inlet					
1	4272	1852	0	2420	5
3	2839	532	0	2307	5
4	2863	1317	0	1546	2
5	10603	578	0	10025	19
6	2820	188	1316	1316	3
7	11993	1066	0	10927	15
8	8668	0	1683	6985	14
9	2313	501	0	1811	1
10	8804	0	1320	7484	14
TOTAL	55175	6034	4319	44821	78
B. Cumshewa Inlet					
11	6885	2952	0	3933	6

Table 10. Summary of egg layers, percent of product which is kelp and eggs, and total weight of eggs in each open-pond in the Queen Charlotte Islands, 1983.

Pond No.	Mean No. Egg Layers	% Kelp By Weight	% Eggs By Weight	Spawn-on-kelp Product (kg)			
				Total		Harvested	
				Kelp & Eggs	Eggs	Kelp & Eggs	Eggs
1	6.5	13	87	4272	3717	2420	2105
3	8.5	11	89	2839	2527	2307	2053
4	7.0	12	88	2863	2519	1546	1360
5	11.0	9	91	10603	9649	10225	9305
6	7.0	12	88	2820	2482	1316	1158
7	10.0	10	90	11993	10794	10927	9834
8	8.0	11	89	8668	7715	6985	6217
9	8.0	11	89	2312	2058	1811	1612
10	8.5	11	89	8804	7836	7484	6661
	TOTAL EGG WEIGHT (Sewell Inlet)				49297		40305
11	6.5	13	87	5996	5217	2952	2568
	TOTAL EGG WEIGHT (Cumshewa Inlet)				5217		2568

Table 11. Change in egg weight on fertilization.

	Adult female		Weight of Egg Sample (g)		
Sample	Length (mm)	Weight (g)	Pre-fertilization	Post-fertilization	Ratio (%)
1	217	134	7.6	11.2	.68
2	210	133	11.7	19.2	.61
3	230	159	8.1	11.1	.73
4	222	138	7.6	12.5	.61
5	225	142	17.9	28.7	.62
6	217	131	13.9	22.2	.63
7	240	159	12.6	17.2	.73
8	213	125	8.0	12.5	.64
9	215	132	9.1	14.0	.65
10	215	134	11.4	17.2	.66
11	270	152	7.5	10.9	.69
12	213	130	11.5	18.3	.63
		TOTAL	126.9	195.0	.65

Table 12. Female roe content of herring in 1982 within impoundments before and after spawning. A. Queen Charlotte Islands. B. North mainland coast.

Area	Pond Number	Total Load (t)	Initial roe content (%)	Final	
				Roe content (%)	% Spawned out
A. Section Cove	2	118	24.2	25.2	20
	*3	100		21.0	20
	4	91		25.1	8
	5	132		25.1	10
	*6	91		18.3	37
	*7	127	24.8	22.9	34
	*8	50		7.9	78
Jedway Bay	*10	100	25.6	19.2	34
B. Pearl Harbor	11	145	24.3	14.3	69
	*12	91	23.9		
	13	181	23.6	22.0	32
	*14	36	24.4	15.8	48
	*15	91	23.9	19.4	30
	*16	73	23.3		
	*17	100	23.3	18.8	42

*Significant amounts of product obtained.

Table 13. Summary of estimated herring tonnage required to produce the spawn-on-kelp product in the open ponds in Sewell Inlet in (1983). Total product includes discard.

Pond No.	A. Total Product (t)	Estimate of Herring Required (t)	B. Processed Product (t)	Estimate of Herring Required (t)
1	4.3	16.3	2.4	7.2
3	2.8	11.1	2.3	9.0
4	2.8	11.1	1.5	6.0
5	10.6	42.4	10.2	40.9
6	2.8	10.9	1.3	5.1
7	12.0	47.4	10.9	43.2
8	8.7	33.9	7.0	27.3
9	2.3	9.0	1.8	7.1
10	8.8	34.4	7.5	29.3
Total	55.1	216.5	44.9	177.1

Table 14. Herring spawn survey observation and egg calculations for Sewell Inlet. Vegetation types are described in detail in Haegele et al. (1979).

Vegetation Type	Area (ha)	Layers	% Cover	Eggs ($10^{-3}m^{-2}$)	Total Eggs (10^{-9})	Required Herring (t)
Kelp	0.22	1.0	20	152	.34	
	0.56	0.5	20	102	.57	
	0.56	1.5	50	380	2.11	
	0.56	1.5	50	380	2.11	
	0.56	1.5	40	320	1.78	
	0.56	5.0	30	565	3.14	
	0.56	1.5	10	132	.73	
	1.11	1.0	10	105	1.17	
	0.56	2.0	30	322	1.79	
	0.56	1.5	75	526	2.92	
	0.83	1.5	70	497	4.14	
	0.83	0.1	10	36	4.14	
	1.67	0.3	60	86	1.43	
	0.56	5.5	100	>1643	9.12	
	0.28	6.0	40	> 720	2.00	
	1.67	6.0	35	> 642	10.69	
	11.61				48.45	380.2
Stringy Reds	0.17	10.0	75	>3207	5.34	
	0.56	10.0	33	>1574	8.73	
	0.56	5.0	33	1035	5.74	
	0.39	1.5	60	562	2.18	
	0.28	3.0	60	1051	2.92	
	0.56	3.0	50	911	5.06	
	0.28	10.0	50	2242	6.22	
	2.78				36.19	284.0
Other Browns	0.56	1.3	10	57	0.31	
	0.17	3.5	80	1537	2.56	
	0.56	1.0	5	29	0.16	
	1.28				3.03	23.8
Seagrass	0.56	4.0	75	1305	7.24	
	0.17	6.0	50	1158	1.93	
	0.56	0.5	10	54	0.30	
	0.50	7.0	80	2340	11.69	
	0.83	0.3	60	161	1.34	
	1.10	3.5	80	1245	13.82	
	0.28	3.0	70	942	2.61	
	0.28	0.5	3	16	0.04	
	0.56	6.0	100	2617	14.52	
	0.11	0.5	30	138	0.15	
	3.30	8.0	80	2653	88.36	

Table 14 (cont'd)

Vegetation Type	Area (ha)	Layers	% Cover	Eggs ($10^{-3}m^{-2}$)	Total Eggs (10^{-9})	Required Herring (t)
Seagrass	1.10	1.0	10	67	0.74	
	0.22	6.0	75	1884	4.18	
	0.56	6.0	80	2027	11.25	
	0.16	6.0	80	2027	3.38	
	10.37				161.55	1267.7
Rockweed	0.56	1.0	20	327	1.82	
	0.28	0.5	20	207	0.57	
	0.28	1.5	30	550	1.53	
	0.56	1.5	90	1063	5.90	
	0.17	0.5	20	207	0.34	
	0.56	3.0	30	1024	5.68	
	0.56	0.5	50	298	1.65	
	2.94				17.49	137.2
Rocks and Cobbles	0.56	1.5	25	128	0.71	
	0.17	4.0	10	136	0.23	
	0.56	4.0	33	449	2.49	
	0.28	0.5	10	17	0.05	
	0.56	2.0	20	136	0.75	
	0.56	0.5	10	17	0.09	
	0.17	1.5	100	510	0.85	
	0.39	0.1	100	34	0.13	
	0.17	5.0	20	340	0.57	
	0.56	1.5	80	408	2.26	
	0.56	1.0	30	102	0.57	
	0.28	6.0	100	1040	5.66	
	0.28	6.0	50	1020	2.83	
	5.05				17.19	137.9
TOTALS	33.98				283.90	2227.80

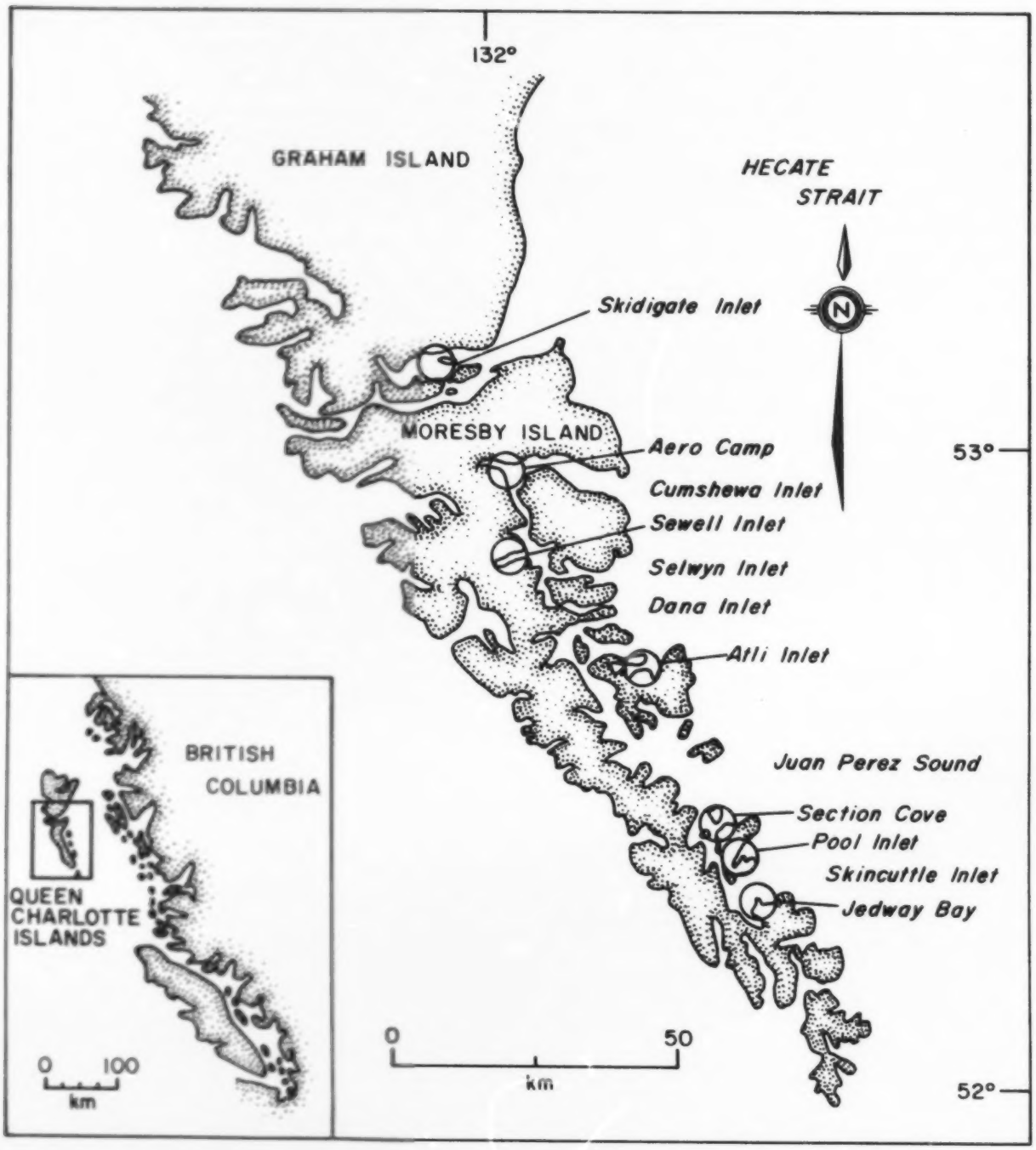

Fig. 1. Locations (circles) of the herring spawn-on-kelp fishery in the Queen Charlotte Islands in 1983.

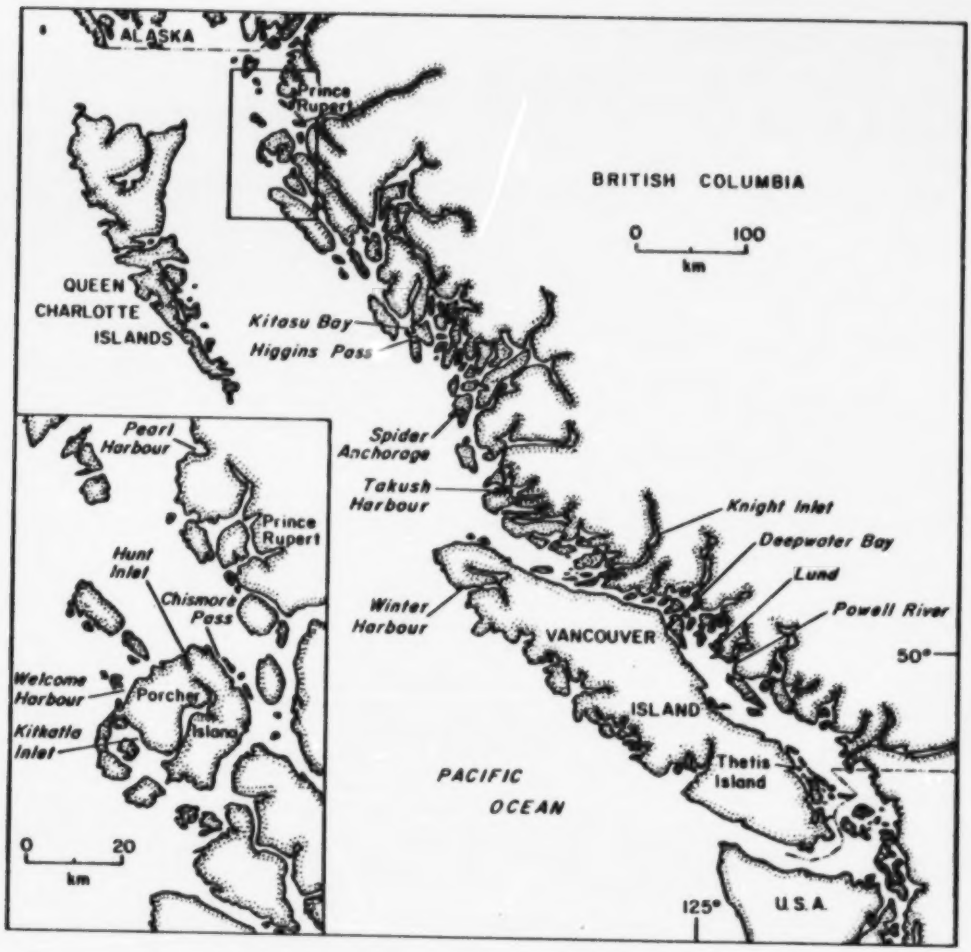

Fig. 2. Locations (place names) of the herring spawn-on-kelp fishery on the mainland coast and adjacent islands of British Columbia.

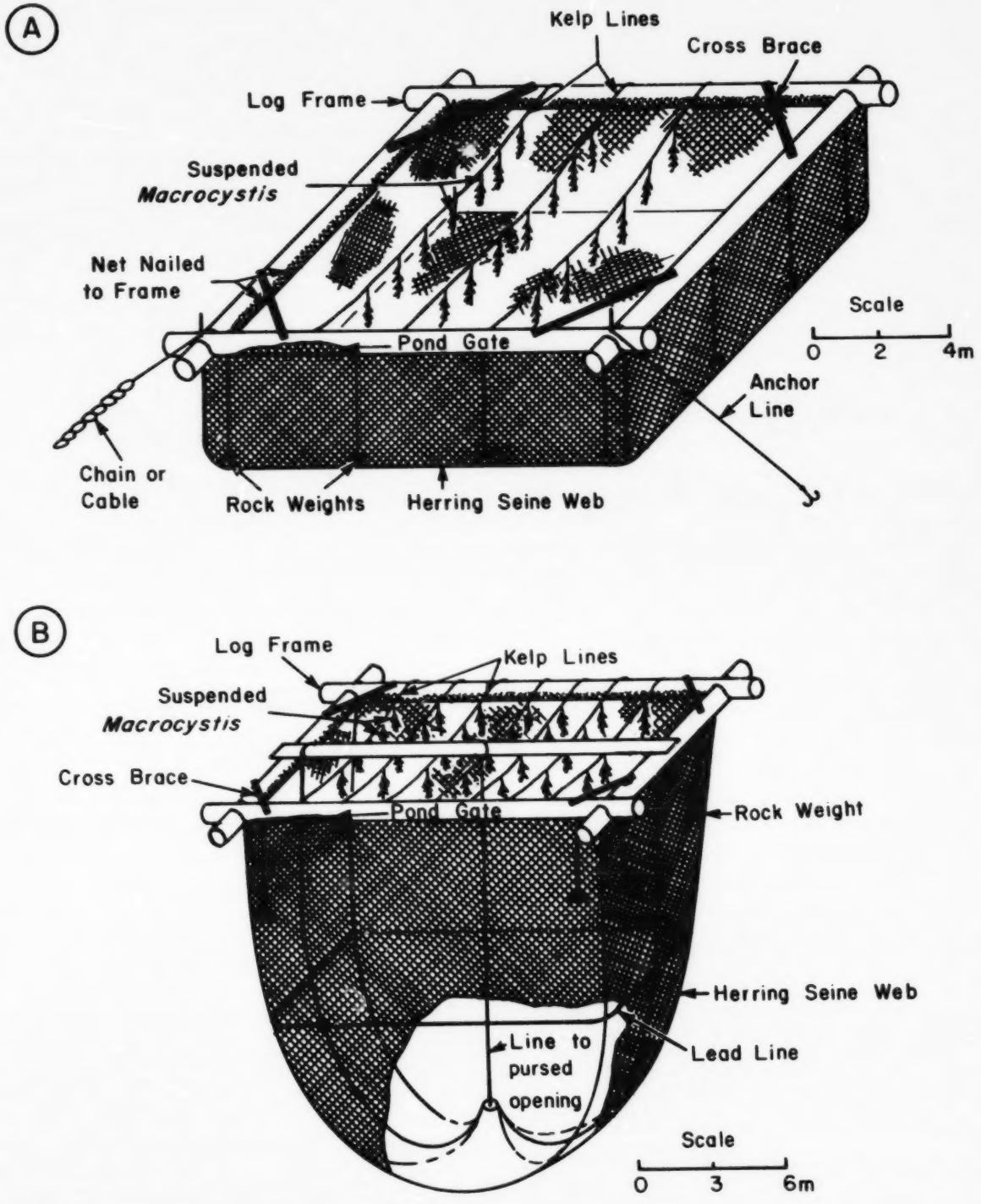

Fig. 3. Diagram of typical herring spawn-on-kelp impoundments. A. shallow-water. B. deep water.

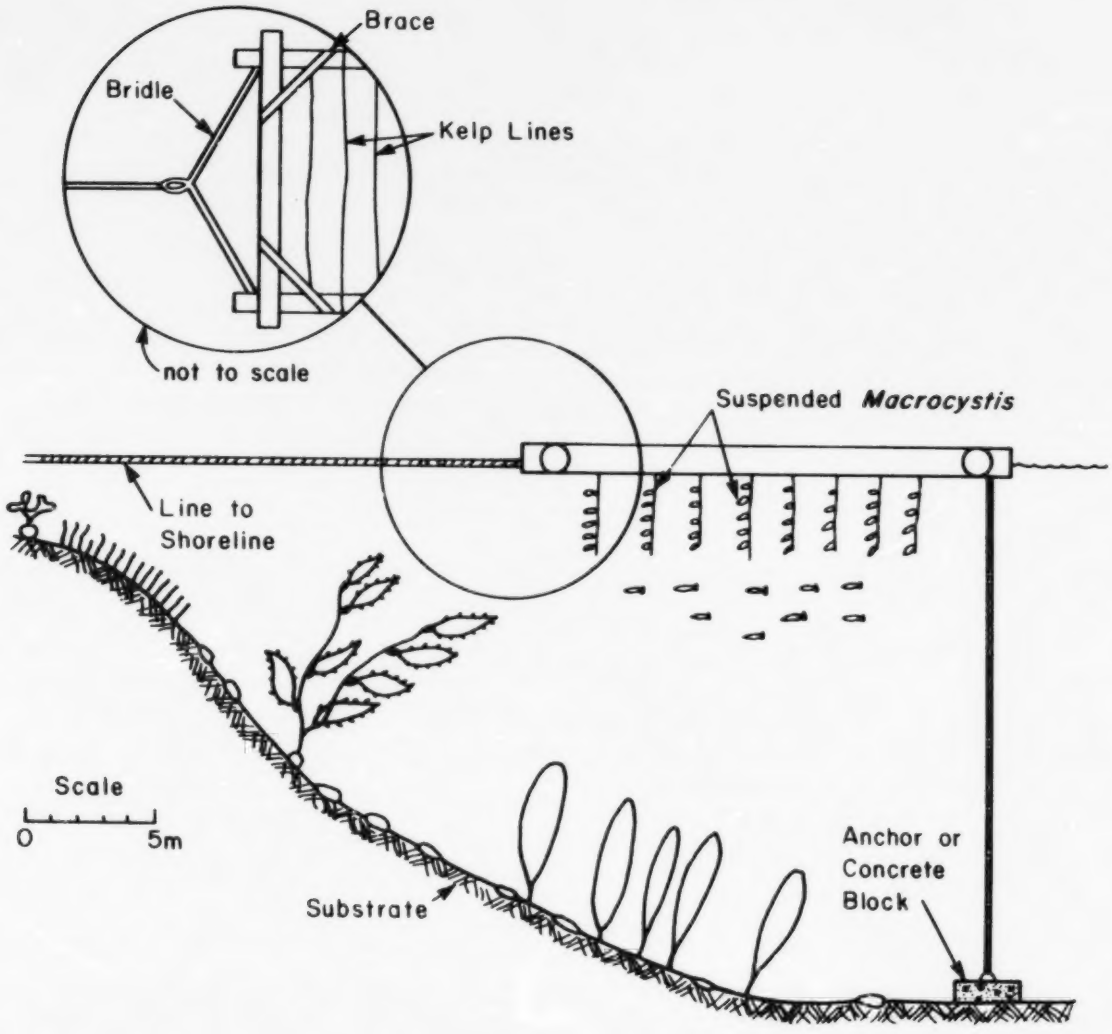

Fig. 4. Illustration of a typical open pond.

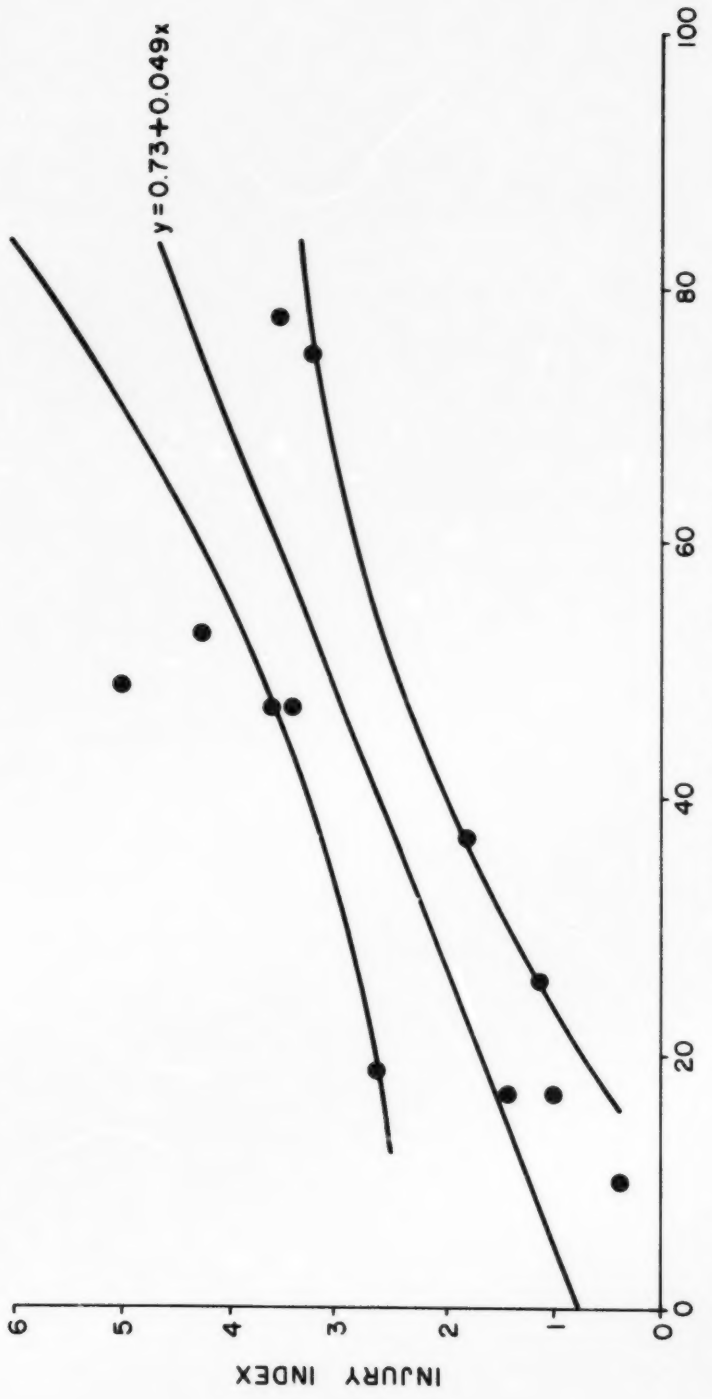

Fig. 5. The relationship between injury index and loading density, with 95% confidence limits.

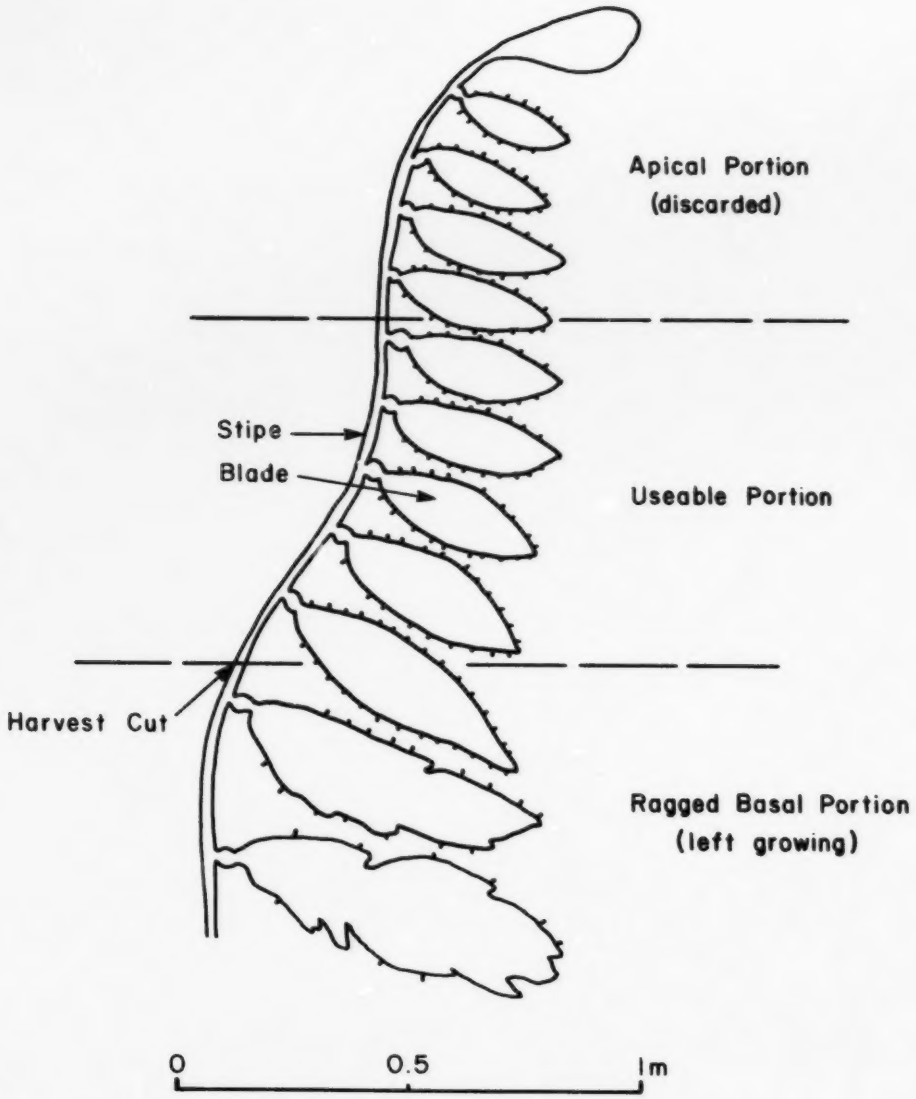

Fig. 6. The portion of a Macrocystis integrifolia plant utilized by the herring spawn-on-kelp fishery.

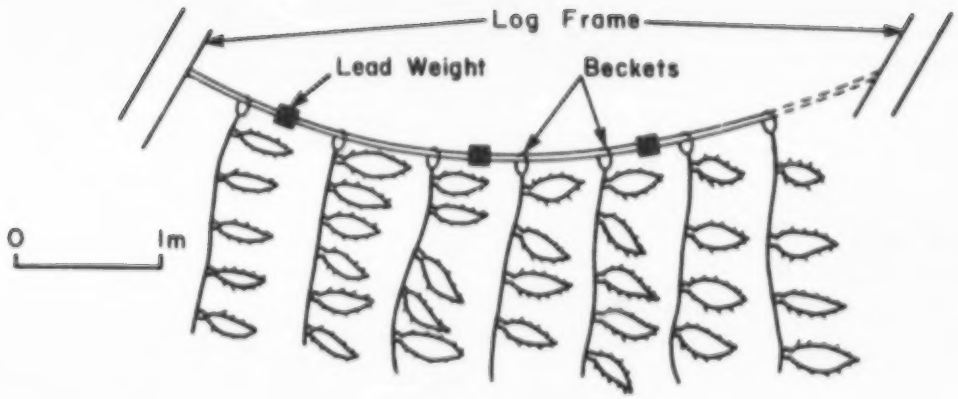

Fig. 7. A diagram illustrating a typical attachment method of Macrocystis to the kelp lines.

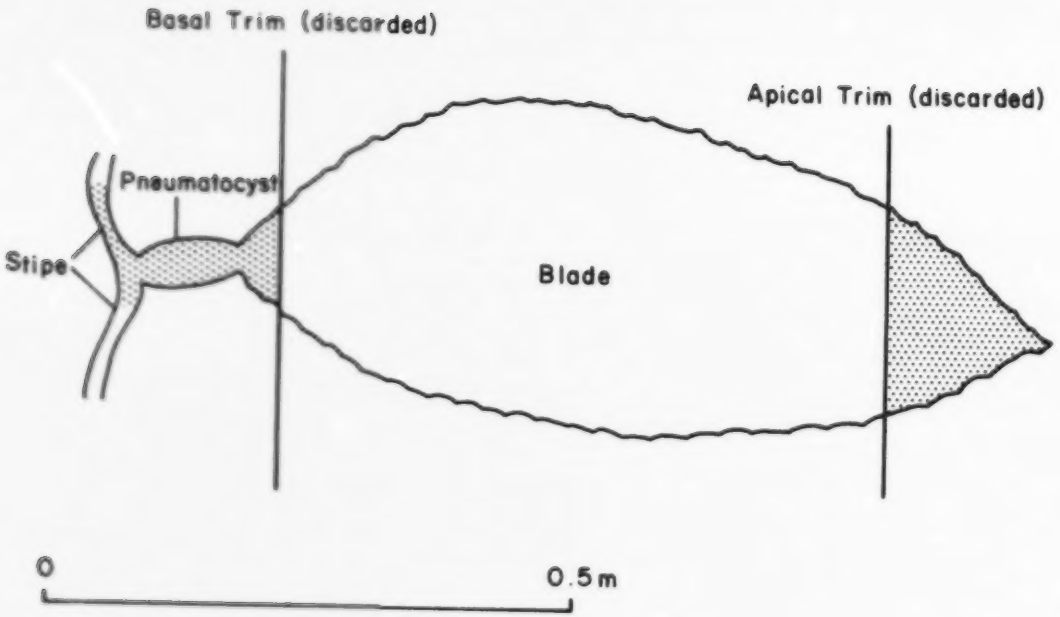

Fig. 8. The portion of a kelp blade removed by trimming.

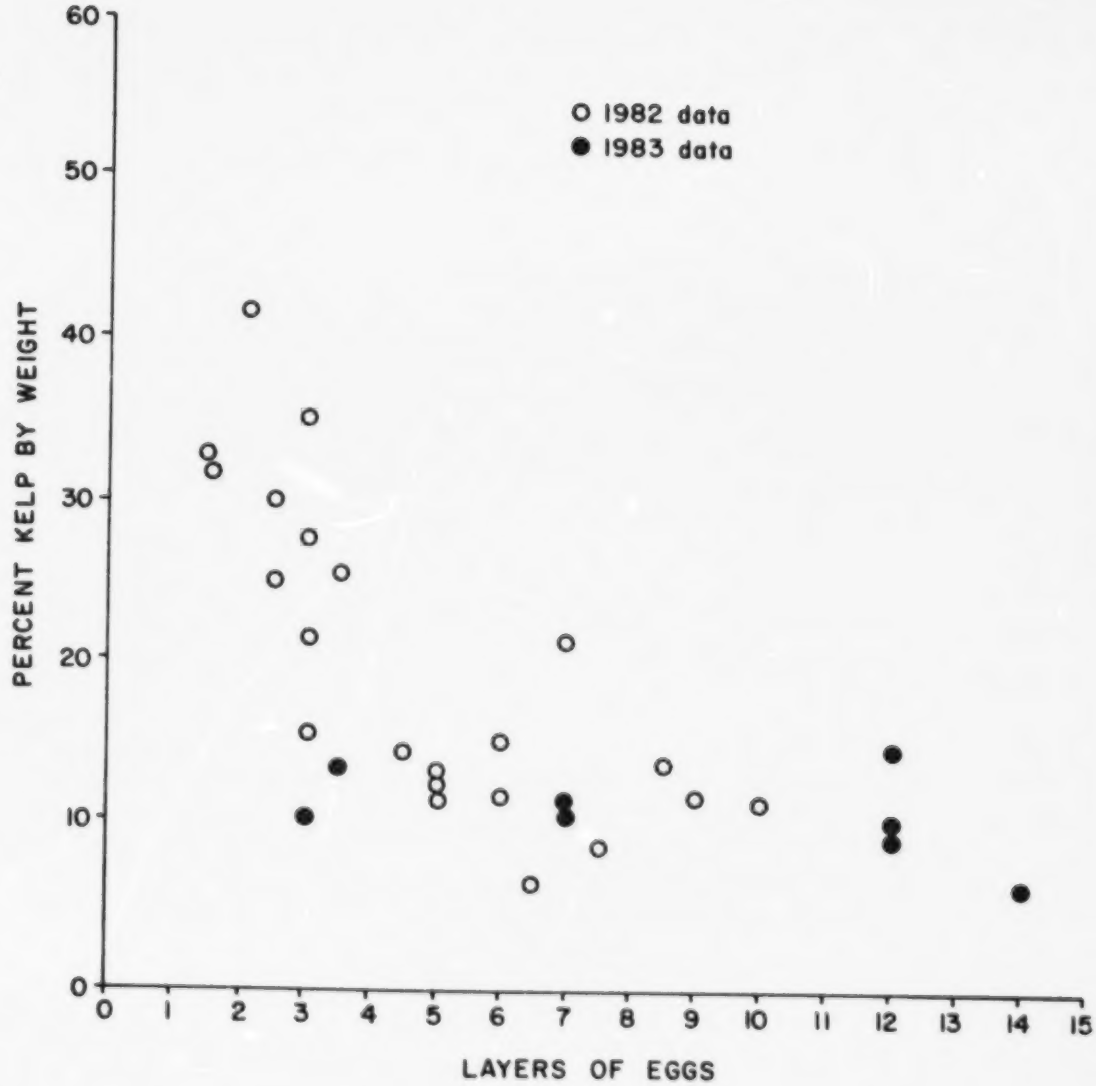

Fig. 9. The relationship between the number of layers of eggs and the percent of spawn-on-kelp product weight represented by kelp.